A PILOT COURSE IN ENGINEERING SYSTEMS ANALYSIS

FINAL DRAFT

INTRODUCTION

It is proposed in this paper to deal with both the substance and the form of a pilot in-house course in Engineering Systems Analysis. In aerospace firms and in government*, it has beenn common management practice to configure working groups of engineers and scientists into large multidisciplinary arrays for projects. The term "matrix organization" is currently used to describe the pro-tempore mix of functional and management project personnel. By a process of iterative design between subsystems, it is possible to reach a set of project objectives set out for major engineering systems. Through the method of repetitive design, the team homes-in on a solution which is perhaps not ideal for any one subsystem but which is presumably ideal or optimum for a totality of subsystems, or for "the system." The process of examination of the system may be entitled Engineering Systems Analysis.

It is almost impossible for any one project manager to achieve intrinsic mastery of the many disciplines represented on his team. However it is possible for a generalized approach to be structured in this area. The application of statistical data analysis techniques is a promising vehicle wherein to frame a course sequence that will offer less than "all things to all men", but which will assist in the fundamental understanding of system performance.

The specific problem to be addressed by this type of course is that of tying together the information processing discipline, if it can so be called, as modified for multiple subsystems. In this discipline there has been a remarkable transition over the past 5 years at the practical level in both industry and government. A typical scientist or engineer working in this field might have an advanced degree in either mathematics, computer operations, electrical engineering or in experimental psychology. It is an interesting point to note that statistical processing has evolved from the convergence of three main fields. Each of these had developed its own symbology, techniques and problem-solving rationale from 3 fairly independent sources. These sources have been mathematics, experimental psychology and electrical engineering. Typically a small cadre of these types of problem-solvers are found throughout technical groups. The premise is made that strengthening and training potential members of these cadres will result in a better technical product.

An in-plant course sequence seems to hold promise for teaching effectiveness since the course design may be tailored directly to suit local "cultural" factors. A visceral set of quick feed-back loops exists within the organization to correct the course

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The notion of an interdependent set of major subsystems being engineered artfully into a harmonious whole, is not all new or invalid. The early marriage of the gangplank to the trireme around 250 B.C. by the Romans is one early example of good subsystem compatibility. Frosch's point is that an overdose of current usage of systems engineering has tended to take away some of the essence of good practice. Chestnut [2] gives a series of major precepts which are basic to the systems approach. In these precepts the thought is central that it is quicker and cheaper in most designs to generate a small-scale math model or system simulation. From the model all of the design requirements of performance, component perturbation, sensitivity analysis, parametric variation and error budgets may be gauged better.

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A group of common tools can be identified which are pertinent to many hardware systems models; This set of tools may be stretched to accommodate to several major disciplines. These major fields would include optics, acoustics, electromagnetics, seismics as well as parts of human engineering and biomedicine. If leading publications of these fields are culled, a pattern of commonality in the mathematical modelling may be noted to exist beneath the semantic language of the particular field. This would imply that if symbology and approach were systematized for a set of applications, then complex sets of problems in individual technical fields would be tractable to a more catholic approach. Examples are found in transformations, matrix manipulations, numerical methods, statistics and probability, etc. Beyond these basic tools, there is a set of subsystems commonly used in systems design for all of these disciplines. Common subsystems are detection and decision-making functions, spatial or multisensor processing, control subsystems and servomechanisms, modulation codings, and others.

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There is evidence that internal problem-solving within the organization would improve in quality by providing technical people with a multi-field set of tools.[5] Frishmuth and Allen propose a model for the technical problem-solving process. They noted that the engineer employed on a problem, rapidly becomes insensitive to acceptance of new alternatives as he becomes positively biased toward a particular technical approach. He thus develops a higher threshold as soon as confirming information is received for a particular route to problem solution. "Openness to additional cues is drastically reduced and is either normalized or gated out." It would follow that the basic solution approach would be enhanced by providing the worker with the ability to translate between fields of technology. The reason for this would be that a wider range of technical alternatives are made available as analogs at the beginning of the problem-solving process. Examples of coherent processing for instance thread through all fields of physical and life sciences in signal analysis. Modulation schemes offer another example.

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For an effective in-house program it is relevant to examine the relative amounts of time allotted under pressure by the technical supervisor.[10] This is highly meaningful because for sustained attendance one must have the backing of the supervisor. The effort of the individual in the course is influenced by his perception of how his superior is linked with the organization and how that supervisor wishes him to allocate his own training effort. One technical organization in DoD, of about 800 technical personnel, showed that first-line supervisors (57) felt that a 15% time allotment was average for "advising and training" subordinates. For second line supervisors, (24) a 10% allocation was given. For laboratory managers, the highest level in the organizational hierarchy, (8) an allotment of 11% was cited. For continuing training by itself, an allocation of 9:5:5 percentage respectively was observed.

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SEQUENCE

The sequence followed was as follows:

I Vectorial representation; matrix manipulation; numerical analysis.

PILOT SEQUENCE

The course sequence which was chosen was as follows:

I Vectorial Representation of Variables: matrix formats; manipulations; vectorial products; orthogonality; independence; Fourier Series; Laplace representation; convolution; Walsh Functions.

The intent here was to develop a base communications in the course, to set the context of terminology and to introduce the sequence to a group which had indicated strength in the topical area. Applications were treated, homework solutions and several representative journal reprints were distributed through the month, between ensuing sessions.

II Linear System Variables: convolution; Laplace manipulations; applications to linear differential equations; damping considerations; impulse responses; system flow diagram; Z Transforms; sampling; numerical methods: Gauss' elimination, matrix inversion.

The goal here was to backtrack into the previous session, held a month previously and to apply the earlier developed tools to simple linear systems. Some linearization schemes were rationalized; sample applications were treated in class to varying depths, generally on a deterministic basis.

III Probability and Statistics: concepts of discrete and continuous variables; sample space; union; intersection; independence; definitions; density function; distribution function; expectancy operator; moments; confidence limits.

It was hoped here to develop tools for treating probabilistic problems. The attempt was to tie in the discrete abstract variable to several physical situations. Applications were framed to repeat the use of material of the sessions.

IV Stochastic Processes: stationary processes; approximations to Gaussian; filtering and averaging; correlation; convolution; cross-correlation; covariance matrix; power spectral estimates; band limiting effects.

The intent in this session was to relate single continuous variables to the array of tools available to handle generalized data bases. Points of relevance were made to tie in the preceeding sessions to space-time variables found in a number of disciplines. Experimental data was developed in handouts and related to different distributions for signal and noise.

V. Stochastic Processes: general review and excercise of modelling tools presented to date; concepts of signals and interference; properties of space and time variables in single dimension case; conditional probability.

Feedback at this point showed that the pace of preceeding sessions was too fast. It was attempted to recapitulate cumulative material.

VI Detector Subsystems: one dimensional signal and noise; detection; decision threshold; optimum processing; receiver operating characteristics; interference effects from ambient noise, system noise, doppler, reverberation, channel uncertainty in a variety of applications.

It had been hoped here that a consistent approach on a set of commonality subsystem functions could be made for ensuing sessions. The detection function is the most common across a variety of disciplines with applications examples in biomedicine, radar, communications, acoustics, optics, and in seismics.

VII Detector Subsystems: optimum detection; prewhitening; Markov noise; detectability criteria; coherent processing; energy detection; confidence measures; Students' t Test.

Continued work on detection functions.

VIII Space-Time Processing Subsystems: multisensor arrays; signal and noise matrices; prewhitening; matched filters; detection; averaging schemes.

The linear array and its variations was the central model for two sessions on spatial subsystems. This had been cited as an area requiring emphasis earlier.

IX Spatial Processors: optimal arrays; lobes in time and space; cohertency; detectability for several configuarations; near field/far field considerations; non-planar wavefronts.

Intent here was to bring in the cumulative set of modeling tools to a group of spatial applications.

X Servomechanism Subsytems: Linear models; closed loop and open loop response; root locus; Bode and Nyquist criteria; optimal control; common non-linearities; phase-plane approach.

This was an area shown strong on the initial poll. The intent here was to give a generally deterministic treatment to this common subsystem. Wiener Hopf and Kalman filtering were treated.

XI Modulation Subsystems- Analog: amplitude, phase and frequency modulation models; deterministic vectorial and frequency models, noise consideration in design; sideband considerations; convolutions; demodulationschemes;

The goal was to establish here a base for definitions and for common communications with the class treatment. A strong indicator had been shown in the poll for this area.

XII Modulation Subsystems-Pulsed: PPM, PCM, PWM, etc. and other pulsedmodels were treated. Relationships between deterministic and band noise-limited cases; system noise and environmental noise budgets.

Second part of modulation treatment.

PRELIMINARY CONCLUSIONS

An evaluation of the first running of this sequence will not be complete for several months. Several qualitative judgements are apparent and will likely be supported by firm data:

1. The collated material represents an excellent in-house reference aside from the detailed class notes on the topical area. It is hoped that this may be built upon, particularly with several representative disciplinary applications in each section.

2. Engendering interest in homework is a challenge. Alternate schemesthat appear viable are either 20 short (10 minutes) problmes or perhaps 5 half-hour problems. Homework was intended to cover about 6 hours at the beginning of the course.

3. A goal for each section might well be to bring the student to a level of competence in the topic where the technical literature was readable to him. A crossection of this representative material can use further work.

4. Attendance was a continuing fight, offset only by continued personal contact. Better schemes for maintaining attendance are needed in a voluntary environment.

5. "Cultural" differences are noted in the educational sources; physics, mathematics and engineering form a group within which communication is fairly easy. Those with chemistry backgrounds form a separate group as do those in the life sciences.

6. The use of an outside "expert" is a good mechanism to program around sensitive group feelings within an organization.

7. The chalkboard-pictorial development is the better approach to the problem posed by the vast amount of material required to be covered.

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TABLE I

Number of Indicators--Strong/Weak Among Respondents

Weak Indicators		Strong Indicators
7	Complex Variables, vector analysis, operators, matrix operations, related material. Problem Groups: basic, first session introductory--sample signals	15
6	Operational Calculus, integration; matrices; line integrals; Rieman space; common operators. Problem Groups: basic; review--sample signals	9
12	Elementary Probability, Stieltjes Integral, common distributions, histograms, independence, tests for dependence, averaging, clipped data, analog data, stationarity. Problem Groups: noise models, signal models; zero crossover, amplitude uncertainty, quantization, sampling	11
17	Applied Engineering Statistics, signal detection probability, conditional probability, common distribution, switching, prediction, filtering parameters, moments. Problem Groups: noise models for environments, processors, source inputs	12
21	Correlation, discrete and continuous, cross correlation tests, goodness of fit, significance, tau translation benefits, reconciliation of statistical approach, orthogonality, independence, error analysis. Problem Groups: noise models, signal models, approximation	1
10	Transforms, Fourier, Walsh, Laplace, clipping, analog, digital data, Z transforms Tou transforms. Problem Groups: transient and steady state responses, noise estimates	6

12	Transforms, Hilbert, Fresnel, common kernel integrals. Problem Groups: spectrum shading, multipath transmissions, media	3
7	Servo System Analysis, flow analysis, sensitivity, feedback, transfer function, impulse response, error representation, statistical approach, smoothing and filtering, prediction compensation input/output relations. Problem Groups: signal input/output consideration, collection analysis techniques control systems, guidance devices	8
10	Fields and Wave Phenomena, array configuration, gain, spacing, shading, phase, signal/noise matrices, near fields, far fields Problem Groups: arrays for sensors, sidelobe exploitation, notching, spatial filtering, ranging, localization, holography, lens design, matched filters	4
10	Detection/Optimization, detection theory, tests criteria, minimax, likelihood ratio, false alarms/dismissals, Wiener-Hopf filters, optimum recovery, sequential. Problem Groups: detection devices, operator aids	1
8	Bayesian Statistics, error probabilities, average cost minimizing, thresholding, complex nets Problem Groups: PR devices, ATR state definition, event indicators, system design	1
7	Modulation, am, fm, ppm, pam, pcm, digital, noise immunity, common error codes, redundancy, error rate estimates, polynomials error codes, fading channels. Problem Groups: telemetry, coding, data transmission, security	8

TABLE II

Distribution of Academic Degrees Among Respondents

none (supplemental schooling)	4
BS, BA	38
MS, MA	15
PhD	9

Disciplines representing mathematics, chemistry physics, electrical engineering, mechanical engineering and life sciences.

PILOT SEQUENCE

The course sequence which was chosen was as follows:

I Vectorial Representation of Variables: matrix formats; manipulations; vectorial products; orthogonality; independence; Fourier Series; Laplace representation; convolution; Walsh Functions.

The intent here was to develop a base communications in the course, to set the context of terminology and to introduce the sequence to a group which had indicated strength in the topical area. Applications were treated, homework solutions and several representative journal reprints were distributed through the month, between ensuing sessions.

II Linear System Variables: convolution; Laplace manipulations; applications to linear differential equations; damping considerations; impulse responses; system flow diagram; Z Transforms; sampling; numerical methods: Gauss' elimination, matrix inversion.

The goal here was to backtrack into the previous session, held a month previously and to apply the earlier developed tools to simple linear systems. Some linearization schemes were rationalized; sample applications were treated in class to varying depths, generally on a deterministic basis.

III Probability and Statistics: concepts of discrete and continuous variables; sample space; union; intersection; independence; definitions; density function; distribution function; expectancy operator; moments; confidence limits.

It was hoped here to develop tools for treating probabilistic problems. The attempt was to tie in the discrete abstract variable to several physical situations. Applications were framed to repeat the use of material of the sessions.

IV Stochastic Processes: stationary processes; approximations to Gaussian; filtering and averaging; correlation; convolution; cross-correlation; covariance matrix; power spectral estimates; band limiting effects.

The intent in this session was to relate single continuous variables to the array of tools available to handle generalized data bases. Points of relevance were made to tie in the preceeding sessions to space-time variables found in a number of disciplines. Experimental data was developed in handouts and related to different distributions for signal and noise.

V. St[illegible] of modelling tools presented to date; concepts of signals and interference; properties of space and time variables in single dimension case; conditional probability.

Feedback at this point showed that the pace of preceeding seesions was too fast. It was attempted to recapitulate cumulative material.

VI Detector Subsystems: one dimensional signal and noise; detection; decision threshold; optimum processing; receiver operating characteristics; interference effects from ambient noise, system noise, doppler, reverberation, channel uncertainty in a variety of applications.

It had been hoped here that a consistent approach on a set of commonality subsystem functions could be made for ensuing sessions. The detection function is the most common across a variety of disciplings with applications examples in biomedicine, radar, communications, acoustics, optics, and in seismics.

VII Detector Subsystems: optimum detection; prewhitening; Markov noise; detectability criteria; coherent processing; energy detection; confidence measures; Students' t Test.

Continued work on detection functions.

VIII Space-Time Processing Subsystems: multisensor arrays; signal and noise matrices; prewhitening; matched filters; detection; averaging schemes.

The linear array and its variations was the central model for two sessions on spatial subsystems. This had been cited as an area requiring emphasis earlier.

IX Spatial Processors: optimal arrays; lobes in time and space; coherency; detectability for several configuarations; near field/far field considerations; non-planar wavefronts.

Intent here was to bring in the cumulative set of modeling tools to a group of spatial applications.

X Servomechanism Subsytems: Linear models; closed loop and open loop response; root locus; Bode and Nyquist criteria; optimal control; common non-linearities; phase-plane approach.

This was an area shown strong on the initial poll. The intent here was to give a generally deterministic treatment to this common subsystem. Wiener Hopf and Kalman filtering were treated.

XI Modulation Subsystems- Analog: amplitude, phase and frequency modulation models; deterministic vectorial and frequency models, noise consideration in design; sideband considerations; convolutions; demodulationschemes;

The goal was to establish here a base for definitions and for common communications with the class treatment. A strong indicator had been shown in the poll for this area.

XII Modulation Subsystems-Pulsed: PPM, PCM, PWM, etc. and other pulsedmodels were treated. Relationships between deterministic and band noise-limited cases; system noise and environmental noise budgets.

Second part of modulation treatment.

PRELIMINARY CONCLUSIONS

An evaluation of the first running of this sequence will not be complete for several months. Several qualitative judgements are apparent and will likely be supported by firm data:

1. The collated material represents an excellent in-house reference aside from the detailed class notes on the topical area. It is hoped that this may be built upon, particularly with several representative disciplinary applications in each section.

2. Engendering interest in homework is a challenge. Alternate schemesthat appear viable are either 20 short (10 minutes) problmes or perhaps 5 half-hour problems. Homework was intended to cover about 6 hours at the beginning of the course.

3. A goal for each section might well be to bring the student to a level of competence in the topic where the technical literature was readable to him. A crossection of this representative material can use further work.

4. Attendance was a continuing fight, offset only by continued personal contact. Better schemes for maintaining attendance are needed in a voluntary environment.

5. "Cultural" differences are noted in the educational sources; physics, mathematics and engineering form a group within which communication is fairly easy. Those with chemistry backgrounds form a separate group as do those in the life sciences.

6. The use of an outside "expert" is a good mechanism to program around sensitive group feelings within an organization.

7. The chalkboard-pictorial development is the better approach to the problem posed by the vast amount of material required to be covered.

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BIBLIOGRAPHY

1. Emerging Shape of Policies for the Acquisition of Major Systems; Marine Technology; 7/69; Robert A. Frosch

2. Systems Engineering Tools; Harold Chestnut; Book; 1965; John Wiley & Sons, Inc., New York, New York

3. Systems Engineering and Modern Technology; C.S. Draper; JASEE; 4/70

4. Role of the Government in Systems Engineering; Frank Hansing and J.A. Vitale; JASEE; 4/70

5. A Model for the Description and Evaluation of Technical Problem Solving; D.S. Frishmuth and T, J, Allen; IEEE Transactions on Engineering Management; Vol. EM-16; May 1969

6. Positive and Negative Biasing Sets; The Effects of Prior Experience on Research Performance; T. J. Allen and D. G. Marquis; IEEE Transactions on Engineering Management; Vol. EM-11 No. 4; 12/64

7. Research on the Human Factor in the Transfer of Technology; W. H. Gruber and D. G. Marquis; Proceedings of MIT Conference on the Human Factors in the Transfer of Technology; 4/68

8. Career Development of Engineers in Industry; Howard M. Miller; JASEE; 6/69

9. A Projective Study of Attitude Towards Continuing Education; I. M. Rubin and H. G. Morgan; Journal of Applied Psychology; V51 #6; 1967

10. Influences Related to Time Allocation of R&D Supervisors; I. M. Rubin, A. C. Stedory and R. D. Willits; IEEE Transactions on Engineering Management; Vol. EM 12-3; 9/65

11. The Problem of Aging Organizations; Edward Roberts; Business Horizons; Winter 1967

12. Mathematical Sequence for Various Engineering Disciplines; G.H. Miller; JASEE; 1/69

					A	S	O	N	D	J	F	M	A	M
	1	2	3	4		5								
DC	3	4	3	3		3	3	2	3	2	2	1		1
OCW	7	5	4	5		3	3	2	2	3	3	3		4
FMSAC	3	3	1	3		1	1	1	1	1		1		
NPIC	4	3	1	1		2	1							
OCS	2	2	2	2		1	2	1		2	1	2		1
TSD	2	3	3	3		2	1	3	2	2	2	3		1
OSP	2	2	2	2			1		1	4		1		1
OEL	3	1	3	3		2	2	2	1	3	1	1		3
OD	1	2	1	1			1	1	1	1				
	26	27	20	23		14	15	11	11	15	9	11		11

TABLE I

Number of Indicators--Strong/Weak Among Respondents

Weak Indicators		Strong Indicators
7	Complex Variables, vector analysis, operators, matrix operations, related material. Problem Groups: basic, first session introductory--sample signals	15
6	Operational Calculus, integration; matrices; line integrals; Rieman space; common operators. Problem Groups: basic; review--sample signals	9
12	Elementary Probability, Stieltjes Integral, common distributions, histograms, independence, tests for dependence, averaging, clipped data, analog data, stationarity. Problem Groups: noise models, signal models; zero crossover, amplitude uncertainty, quantization, sampling	11
17	Applied Engineering Statistics, signal detection probability, conditional probability, common distribution, switching, prediction, filtering parameters, moments. Problem Groups: noise models for environments, processors, source inputs	12
21	Correlation, discrete and continuous, cross correlation tests, goodness of fit, significance, tau translation benefits, reconciliation of statistical approach, orthogonality, independence, error analysis. Problem Groups: noise models, signal models, approximation	1
10	Transforms, Fourier, Walsh, Laplace, clipping, analog, digital data, Z transforms Tou transforms. Problem Groups: transient and steady state responses, noise estimates	6

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